

INFORMATION REPORT

SUBJECT Standard Fuels Used for Internal Combustion
Marine Engines in the USSR

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SUPPLEMENT TO
REPORT NO.

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- (a) By sulphur content:

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- (b) By the content of resinous substances:
- (1) Low resinous with a content of up to 17% resin
 - (2) Resinous with a content of from 18 to 35% resin
 - (3) High resinous with a content of more than 35% resin
- (c) By the temperature of the thickening of the oil fraction with an Engler viscosity of 7 degrees centigrade ($7/E_{50} = 7/$):
- (1) Low paraffin with a thickening temperature of minus 16 degrees centigrade and lower
 - (2) Paraffinous with a thickening temperature of from minus 15 to plus 20 degrees centigrade
 - (3) High paraffinous with a thickening temperature higher than 20 degrees centigrade.
3. Fuels are divided into 48 types according to the quality of gasolines, kerosenes and oils:
- (a) Gasolines:
- (1) Petroleum that contains high octane gasoline (an octane count of 72 and more)
 - (2) Petroleum that contains medium octane gasoline (an octane count of from 65 to 71)
 - (3) Petroleum that contains low octane gasoline (a count of 65 and less)
 - (4) Petroleum not containing gasoline.
- (b) Kerosenes:
- (1) Petroleum containing tractor kerosene (octane count of 40 and more)
 - (2) Petroleum containing intermediate kerosene (octane count of 30 to 39)
 - (3) Petroleum containing low octane kerosene (count of less than 30)
- (c) Oils:
- (1) Petroleum containing high index oil with a specific weight of the oil fraction 0.903 and lower
 - (2) Petroleum containing medium index oil with a specific weight 0.904 to 0.927
 - (3) Petroleum containing a low index oil with specific weight 0.927 and more
 - (4) Petroleum not containing oils.

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4. Fuels used in internal combustion ship engines are divided into two basic types:
 - (a) Fuels of the furnace type, that is, solarium and Diesel fuel
 - (b) Residual fuels or simply residues (mazuts).
5. The basic criterion for selecting fuels for ship engines is the degree of speed of the latter. Thus ship engines are divided into three groups:
 - (a) Slow speed with 500 revolutions per minute and average cylinder stroke of four to six meters per second.
 - (b) Medium speed from 500 rpm to 1,000 rpm and an average cylinder stroke of from six to nine meters per second.
 - (c) High speed with 1,000 rpm and an average cylinder stroke of nine to 12 meters per second.
6. In order to avoid trouble in the operation of ship engines, the Merchant Registry issued a set of rules designating which fuels should be used for which engines. The factories producing the engines state which type of fuel is to be used in them and different fuels may be substituted only after controlled experimentation. According to the rules of the Merchant Registry the ignition temperature for heavy fuels should not be lower than plus 65 degrees centigrade (according to Martens-Pensky).
7. For low speed engines, motor fuel (GOST 1667-42) either residual or mixed is used:
 - (a) Motor fuel M-3 is a mixture of mazut with solarium fractions. The Engler viscosity of this fuel is 50 at 50°C. The ignition temperature is 65°C and the thickening temperature is 5°C. This fuel is used widely in ship engines not requiring any kind of pre-heating of the fuel. Glavneftesbyt (Head Directorate of Petroleum Marketing) of the Ministry of the Petroleum Industry recommends the use of M-3 for low speed, low power engines of 250 to 500 rpms developing 100 hp. M-3 can be used also as a starting fuel for engines operating with heavy-type fuels M-4 and M-5.
 - (b) M-4 is a residue from the cracking process. The Engler viscosity is 7.5° at 50°C, the stiffening temperature is minus 5°C and the ignition temperature is plus 65°C. M-4 may be used by heating it with hot water at a temperature of 45° to 50°C, but in the summertime when the temperature of the surrounding atmosphere is high enough, this fuel can be used without pre-heating. This fuel is used principally in slow-speed engines having a comparatively large cylinder power (more than 100 effective hp per cylinder) if the fuel is filtered carefully and the water removed (about two per cent water may be expected to appear in the fuel).
 - (c) Motor fuel M-5 like M-4 is a residual fuel. The Engler viscosity is 9.0° at 50°C, the thickening temperature is plus 5°C and the ignition temperature is 90°C. Several types of this fuel have an even higher thickening temperature (plus 35°C). M-5 requires pre-heating from 40° to 70°C, depending upon the type of fuel, in order to lower the viscosity to three to five degrees. In this condition the fuel has the

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proper degree of fluidity. This fuel like M-4 is used principally in low-speed engines of comparatively large cylinder power (more than 100 effective hp per cylinder), providing that the fuel is carefully filtered and water removed.

8. Solarium oil (GOST 1666-42) is used for medium-speed engines. Solarium is a distilled petroleum product having a boiling point of from 240° to 260°C and a distilling fraction of 55 to 60% up to 350°C. The ignition temperature of solarium is 125°C (according to Brenken), and the thickening temperature is -20°C. The viscosity of solarium is 1.2 to 1.75 degrees Engler at 50°C. The high quality of solarium makes it especially adaptable for use in medium-speed engines on account of its comparative safety from fire hazard and on account of the fact that it sprays well into the cylinders of the engine. Solarium is also used for a preparation of mixed fuels (M-3). A substitute for solarium is Diesel fuel.
9. Summer and winter Diesel fuel (GOST 305-42) and Diesel aviation fuel (OST VTU 161-44) are used for high-speed engines.
 - (a) Diesel auto tractor summer fuel is an intermediate product of the cracking process, consisting of heavy kerosene fractions and light solarium fractions. Summer fuel has a thickening temperature of minus 10°C and an ignition temperature of 65°C. Its viscosity equals 1.4 to 1.7 degrees Engler at 20°C. At 350°C this fuel contains 85% topping.
 - (b) Diesel auto tractor winter fuel is an intermediate product of the cracking process, consisting of heavy kerosene fractions and light solarium fractions. Winter fuel has a thickening temperature of minus 35°C and an ignition temperature of 65°. Its viscosity equals 1.4 to 1.7 degrees Engler (at 20°C). At 350°C the fuel has 85% topping. The industrial price of Diesel auto tractor fuel in 1951 averaged 640 rubles per ton.
 - (c) Diesel aviation fuel of the type "AD 40-340-1.1-1.5" is a fuel of very high quality used in high-speed engines having self-ignition. The designation of this fuel has the following meaning: AD means aviation "Diesel" fuel, 1.1-1.5 means that the viscosity is from 1.1 to 1.5 degrees Engler (at 20°C), 340 means that at 340°C the maximum fraction (97%) is distilled and finally that the cetane count of this fuel should not be less than 40. The ignition temperature of this fuel is 28°C and the thickening temperature minus 55°C.
10. Besides the fuels prescribed by the standard there is still another series of non-standard fuels used in ship engines, and the characteristics of which depend mainly on their origin. The use of non-standard fuels in ship engines requires the concurrence of organs of the Merchant Registry and the quality of these fuels should approximate the requirements of the engine manufacturer.
11. The minimum temperature at which a fuel ignites itself and burns without the action of any kind of outward source of ignition is one of the most important characteristics of a given fuel as it shows the degree of suitability of the latter for use in engines. The temperature of self-ignition of a given fuel in relation to the pressure exerted at the end of the compression process has special meaning in engines.

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12. Fuel is injected into the cylinder of an engine at rather low temperatures (40° to 60°C). This fuel temperature is much less than the temperature of the compressed air in the cylinder (600° to 700°C). The intermediate time from the moment of the actual entrance of the fuel into the cylinder to the moment that compression begins in the cylinder is called the period of delay in self-ignition and is measured in thousandths of a second or in degrees of angle of crankshaft revolutions. The length of the period of delay in self-ignition depends on many factors, first of all, on the physical (the heating drop, evaporation, the heating of the vapors to the temperature of the compressed air, etc) and chemical (type of fuel, its structure, speed of reaction of oxidization of the fuel with oxygen from the air, etc).
13. The length of the period of delay in self-ignition determines the quality of the fuel which is in turn responsible for the ease of starting of the engine, smoothness of operations, etc. The quality of self-ignition of the fuel also exerts an influence on the completeness and fullness of burning, specific consumption, extent of after burning, etc or in other words, on the entire burning process.
14. A series of laboratory and motor tests have been devised for the evaluation of the self-igniting quality in fuel. Of the motor methods in the USSR the most widely used were the methods of determining the critical degree of compression and those determining the period of delay in self-ignition.
15. The idea of the method of determining the critical degree of compression is, that on a special four-stroke, one-cylinder engine, having a compression degree of from seven to 23 and having a Diesel head (the normal one being used for determining the octane count of gasoline and other light fuels) it is possible to determine a minimum degree of compression at which the fuel being tested ignites itself. This degree of compression is called critical. The lower the critical degree of compression the higher the quality of fuel as far as self-ignition and burning is concerned.
16. The method of determining the period of delay in self-ignition is based on the taking of detailed indicator diagrams from the engine used in the test. As in the case of determining the critical degree of compression, an engine with a variable degree of compression is used for this test, and the fuel is also tested in the normal working of an engine by injecting the fuel at temperatures ranging from 100° to the highest absolute point. In order to determine the extent of the delay in self-ignition, a special device is used which records the moment of the injection of the fuel and the moment that it is ignited.
17. Practically, it has been proven much easier not to use the absolute critical degree of compression and the period of delay in self-ignition but simply to compare these qualities with the standard ones for standard fuels. For this purpose at first two chemically pure hydrocarbons were used of which the first, cetene, has the most absolutely low point of self-ignition (that is, at a low critical degree of compression and a short period of delay in self-ignition and the second, mezitline, to the contrary has the most difficult degree of self-ignition. At present there are new standards for fuel; cetane ($\text{C}_{16}\text{N}_{34}$) is the most stable in storing and alpha-methylnaphthalene ($\text{C}_{11}\text{N}_{10}$) is the cheapest. The grading of fuel

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for engines as regards self-ignition is done by the so-called cetane count showing the per cent by volume of cetane contained in the fuel in a mixture of it with alphas-methylnaphthalene which when used experimentally in an engine with a changeable degree of compression shows the equivalent in self-ignition with the fuel being tested. The self-ignition degree of cetane corresponds to the figure 100 and the self-ignition degree of alphas-methylnaphthalene corresponds to the figure zero. The cetane count is determined usually by the method of coinciding ignitions. If the critical degree of compression is found for a given fuel, then two mixtures of standard fuels are made. These fuels differ from each other by not more than four units of cetane count, one of which gives a coincidence of ignition at a lower and the other at a higher degree of compression than the degree of compression found for the fuel being tested. Then by the method of interpolation, the percentages of the mixture are found. This mixture has the same critical degree of compression as the fuel being tested. The percentage of cetane in this mixture is called the cetane count of the fuel.

18. The difference between the cetane and the cetene count of the fuel is that the cetane count equals $7/8$ of the cetene count. In everyday experiments, the cheaper secondary standard fuels (the tarses of which are determined in relation to the primary fuels) having a lower cetane count (for example Diesel fuel with a cetane count not less than 60 and green soap with a cetane count of not more than 25) are used. The cetane count is a comparative quantity and is not an absolute measure of the quality of self-ignition in an engine as the latter depends also on the form of the combustion chamber and other factors. The cetane counts of fuels indirectly showing the period of delay in self-ignition are selected in accordance with the kind of engine and the degree of its speed and power as follows:
 - (a) For low-speed engines -- from 35 to 50
 - (b) For high-speed engines -- from 40 to 60.
19. The cetane counts of Diesel fuels made from Soviet petroleum vary from 40 to 70, that is, they completely fulfill the specifications for fuels for high-speed engines.
20. Besides determining the cetane count by means of special engines, there is also a device called the "bomb" which is used for this purpose in which the conditions of pressure and temperature correspond with those found in an actual engine. In high-speed and forced-injection engines the cetane content of the fuel is often raised by the addition of high cetane components. Some of these are peroxide acetyls, tetralene and others, and also nitro combinations (ethyl nitrate, amyl nitrate and others). For example, an addition of one percent acetyl peroxide raises the cetane count from 40 to 60. Any increase in the amount of an addition renders the action of the addition less effective.
21. Another effective means of raising the cetane count is by processing fuels with selective solutions, the action of which is based on the elective dilution of harmful components in the fuel (for example, aromatics). The solutions used for this purpose are furfural, liquid sulphurous gas and others.

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